State of Ohio
Environmental Protection Agency

Division of Drinking and Ground Waters

Technical Guidance Manual for Ground Water Investigations

Chapter 6

Drilling and Subsurface Sampling

April 2007

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Director : Chris Korleski

TECHNICAL GUIDANCE
MANUAL FOR
GROUND WATER INVESTIGATIONS

CHAPTER 6

Drilling and Subsurface Sampling

April, 2007
Revision 1

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PREFACE

This document is part of a series of chapters incorporated in Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (TGM), which was originally published in 1995. DDAGW now maintains this technical guidance as a series of chapters rather than as an individual manual. The chapters can be obtained at http://www.epa.state.oh.us/ddagw/tgmweb.aspx

The TGM identifies technical considerations for performing hydrogeologic investigations and ground water monitoring at potential or known ground water pollution sources. The purpose is to enhance consistency within the Agency and inform the regulated community of the Agency's technical recommendations and the basis for them. In Ohio, the authority over pollution sources is shared among various Ohio EPA divisions, including the Emergency and Remedial Response (DERR), Hazardous Waste Management (DHWM), Solid and Infectious Waste (DSIWM), and Surface Water (DSW), as well as other state and local agencies. DDAGW provides technical support to these divisions.

Ohio EPA utilizes ***guidance*** to aid regulators and the regulated community in meeting laws, rules, regulations and policy. Guidance outlines recommended practices and explains their rationale. The Agency may not require an entity to follow methods recommended by this or any other guidance document. It may, however, require an entity to demonstrate that an alternate method produces data and information that meet the pertinent requirements. The procedures used to meet requirements usually should be tailored to the specific needs and circumstances of the individual site, project, and applicable regulatory program, and should not comprise a rigid step-by-step approach that is utilized in all situations.

Major Changes from the February 1995 TGM

The Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring (TGM) was finalized in 1995. This guidance document represents an update to Chapter 6 (Drilling and Subsurface Sampling). Listed below are the major changes from the 1995 version.

1. Expanded text for clarity and updated information.

2. Added information on solid-barrel samplers.

3. Added information on the potential for core losses when using coring methods.

4. Removed information on sample storage and preservation for chemical analysis.

5. Modified the decontamination process. This included removing the reference to using ASTM Type II water for decontaminating equipment.

6. Included references to new documents that has become available since 1995 version, including:

    - Updated existing references.

    - Added new ASTM reference for selection of drilling methods for environmental site characterization.

    - Added reference to the federal Field Sampling and Analysis Technologies Matrix and Reference Guide.

    - Added reference to the State Coordinating Committee on Ground Water Technical Guidance for Well Construction and Ground Water Protection.

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CHAPTER 6
DRILLING AND SUBSURFACE SAMPLING

Drilling and sampling of boreholes represent important components of virtually all ground water investigations. Drilling should minimize disturbance of the subsurface. Methods should identify saturated zones and sample formation materials to characterize the subsurface and, subsequently, allow for proper monitoring well installation. Appropriate quality assurance/quality control (QA/QC) procedures, including equipment decontamination and measures to prevent cross-contamination of subsurface zones, should be implemented. The following sections discuss drilling, subsurface sampling, and QA/QC.

FACTORS AFFECTING CHOICE OF DRILLING METHOD

The choice of drilling method should be based on expected performance when hydrogeologic conditions, contaminant type and presence, and the nature and scope of the investigation are considered. Additional factors include site access and equipment availability.

HYDROGEOLOGIC CONDITIONS

For most sites, hydrogeology is the most important factor in drilling method selection. If work is just beginning, initial literature and data searches for the surrounding area should be conducted to obtain a general knowledge of the local geology and the occurrence of ground water. If borings have been performed on or near the site, available logs may prove valuable.

Hydrogeologic conditions affecting the choice of methods include:

- ***Material Consolidation:*** Some methods can penetrate unconsolidated materials, but not rock.
- ***Material Cohesiveness:*** When drilling through cohesive material, an open borehole can be maintained and a well can be installed directly. However, when penetrating less stable and collapsing formations, the method should allow casing or the drill string to be used to maintain the borehole.
- ***Thickness of Formation:*** If thin, intermittent sand lenses are of interest, methods offer differing capabilities of allowing their identification. Most, however, can detect a thick, high-yield zone.
- ***Presence of Fractures:*** Fractures in rock and porous, unconsolidated material may cause lost circulation of fluids and hinder penetration. Where this is a problem, casing may have to be advanced closely behind the bit. Therefore the chosen method should permit casing installation during drilling (Davis et al., 1991).

- ***Presence of Cobbles and Boulders:*** The presence of cobbles and boulders can hinder advancement of a bit. Where cobbles and boulders are present, a method should be chosen that can penetrate the materials effectively.

- ***Heaving Sands:*** Some equipment may be limited in its ability to drill below the water table, particularly in loose granular soils. With some methods, sand or gravel can flow into the drill stem, making sample retrieval and well installation difficult. Special equipment may be needed.

Aller et al. (1991) developed a rating system to determine applicable drilling methods for various generic geologic situations. The Federal Remediation Technologies Roundtable has produced a simpler matrix of drilling methods that is available at http://www.frtr.gov/site/samplegif.html). Methods were rated for versatility, sample reliability, relative cost, availability, relative time required for well installation and development, ability to preserve natural conditions, ability to install particular well diameters, and relative ease of well completion and development. This system can help narrow the choices to those most applicable to site conditions.

CONTAMINANT TYPE AND PRESENCE

Characteristics of contamination that can affect the choice of drilling method include:

- ***Contaminant Phase:*** If contaminants are present in the gaseous phase, the method should contain the contaminants, minimize losses to the atmosphere, and reduce any explosive potential. If free product is present, methods should be utilized to detect it. In certain situations, type and amount of contamination can be anticipated.

- ***Potential for Cross-Contamination:*** To monitor a zone of unknown ground water quality that underlies a contaminated zone, adequate precautions should be taken to prevent cross-contamination. Generally, the portion of the borehole opposite an upper water-bearing zone should be drilled, cased, and grouted separately. A smaller diameter borehole then should be completed through the grouted casing into the underlying zone. This process, often referred to as "telescoping", and should prevent migration of contaminants from the upper zone into the lower zone. Hackett (1987) provided specific details for this technique when hollow-stem augers are used.

- ***Concentration of Contaminants:*** Where high concentrations of contaminants are present, extra precautions for equipment decontamination and disposal of fluids (if used) and cuttings should be considered. Fluid and cuttings may need to be disposed as hazardous waste. Thus, waste minimization may be a major concern for method selection.

NATURE AND SCOPE OF INVESTIGATION

The drilling method should allow for identification of subsurface geology and water-producing zones based on the nature and scope of the investigation. Factors that can dictate method selection include:

- ***Monitoring Well Depth and Diameter:*** The method must be able to meet the depth and diameter requirements of proposed monitoring wells. Casing typically ranges from two to four inches in diameter. Wells that will be pumped for tests or remediation may need to be at least 4 inches in diameter to allow access for pumps and to provide adequate yield. Sufficient space must be present in boreholes to allow adequate installation of seals and filter packs, unless pre-packed well screens are used with small diameter wells (see Chapter 15 - Use of Direct Push Technologies for Soil and Ground Water Sampling).

- ***Knowledge of Site Hydrogeology:*** If little or no background information is available, it may be desirable to perform a small scale hydraulic test on selected zones or sample ground water for contaminant analysis. The ability to collect samples during drilling varies according to the method used and the ability to pump the zone of interest. In some cases, a screened drill string may be employed. In other cases, a well point or in-situ sampler (e.g., DPT sampler, see Chapter 15 - Use of Direct Push Technologies for Soil and Ground Water Sampling) can be driven ahead of the borehole base. The driven tool is then pumped to remove fine sediment and provide a sample. After sampling, the device is retrieved and drilling is resumed. These tools may be used with any method that allows easy access to the borehole bottom. However, they should only be used as a screening tool. A well point should not be used as a permanent monitoring well.

OTHER FACTORS

Physical features alone potentially can influence the choice of drilling method. Moving large equipment over rough or muddy terrain or into tight spaces between physical obstructions may be required. Rig movement can be hindered by overhead powerlines or structures common around industrial areas. Regional geology and demand play a major role in determining equipment availability, which is another factor.

DRILLING METHODS

The following discussion provides a general description of recommended drilling methods for monitoring well installation. These include hollow-stem auger, cable tool, and rotary techniques. Again, site conditions should dictate the selection. One (or a combination) should be adequate to satisfy most situations.

HOLLOW-STEM AUGER

Hollow-stem augers are readily available in Ohio, and are recommended for penetrating unconsolidated materials. Auger rigs are light and maneuverable. Each section or flight is typically 5 feet in length. A head is attached to the first flight and cuttings are rotated to the surface as the borehole is advanced (Figure 6.1). A pilot bit (or center bit) can be held at the base of the first flight with drill rods to prevent cuttings from entering. When the bit is removed, formation samples can be obtained through the auger using split-spoon or thin-wall samplers. Generally, fluids do not need to be introduced; therefore, ground water quality alteration usually is avoided. Hackett (1987, 1988) has reviewed procedures for using hollow-stem augers. ASTM D 5784-95 (reapproved 2000) also provides guidance.

One of the major advantages of hollow-stem augers is that they allow for well installation directly through the auger into non-cohesive material. Table 6.1 shows auger sizes typically available. The inside diameter of the hollow-stem is generally used to specify size, not the diameter of the hole drilled. Appropriate clearance should be available to provide effective space for materials placement. The augers are removed as the well is installed (SCCGW, 2000). If space is insufficient, bridging of the materials may bind the casing and auger together, resulting in the extraction of the well as the auger is removed (Hackett, 1988). Additionally, insertion of a tremie pipe may be difficult.

The most widely available size is 3.25-inch (6.25-inch outside diameter, including the flights), which has been used to install 2-inch (2.378 outside diameter) monitoring wells; however, this allows limited access. It is doubtful that materials can be placed adequately at depths below 15 feet considering the relatively small amount of clearance offered. The minimum size that should be used for installation of 2-inch diameter casing is 4.25 inches; however, larger augers may be necessary.

The depth capability of hollow-stem augering depends on site geology and the size of the rig and stem. In general, greater depths can be reached when penetrating clays than when penetrating sands; however, clays may cause the auger to bind, which limits depths. The size of the rig and stem affects the downward pressure and torque on the stem. Greater depths may be reached by smaller augers. Depths of 200 + feet can be reached utilizing a 4.25-inch hollow-stem auger, whereas 10.25-inch augers can reach a maximum depth of approximately 75 feet.

Hollow-stem augering presents some disadvantages. It cannot penetrate cobbles and boulders nor most rock formations. In some cases, obstructions can be pushed aside by spinning the augers in-place. When this is not successful, replacing the pilot assembly with a small tri-cone bit may allow penetration. Additionally, carbide-tipped cutting teeth have been developed for the upper portions of weathered bedrock, which may be useful when the unconsolidated/bedrock interface is the zone of interest.

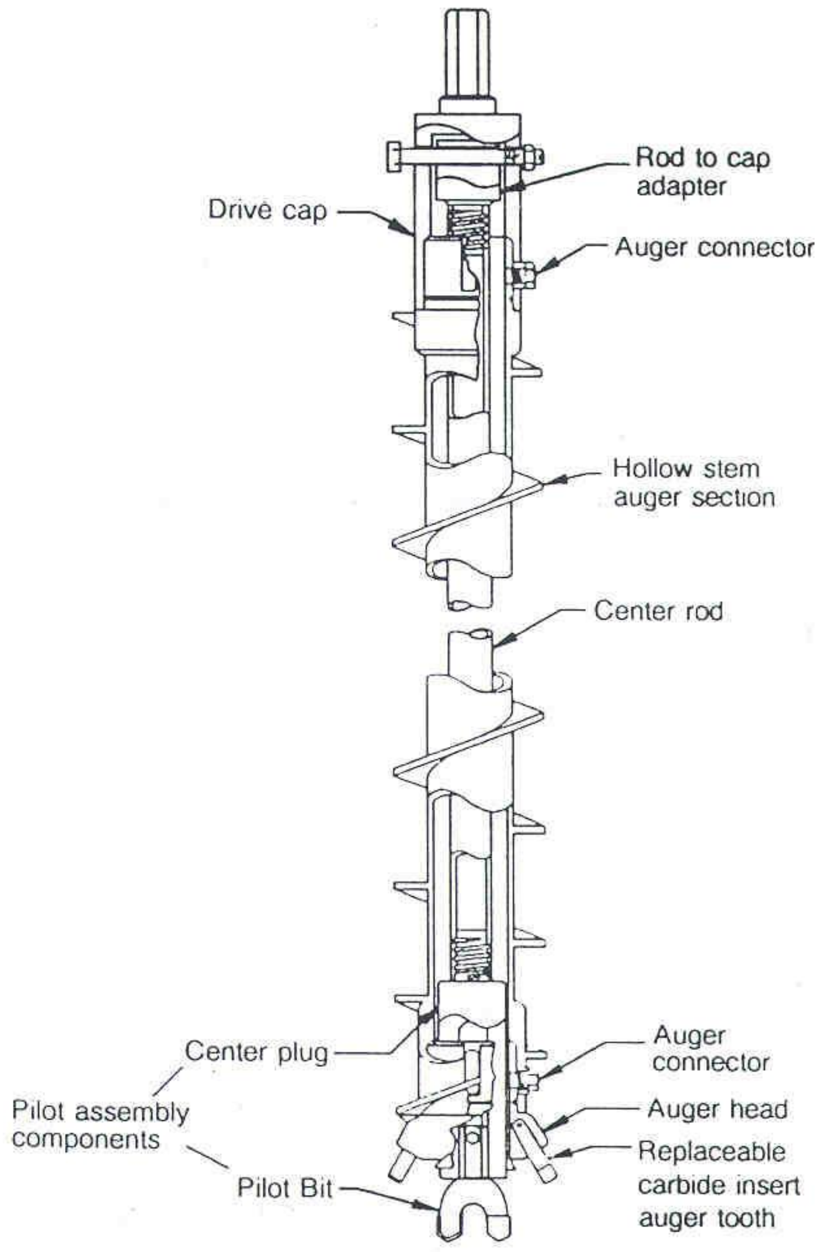


Figure 6.1 Components of hollow-stem auger (Source: Aller et al., 1991; after Central Mine Equipment, 1987).

Although augering generally allows for adequate identification of water-producing zones, the technique may cause clay and silt to smear on the borehole wall, preventing the identification of low yield zones and hindering well development (ASTM Method D6286-98). This smearing may be beneficial if it serves to impede vertical ground water movement, which reduces the potential for cross-contamination between subsurface zones. However, the possibility of this circumstance occurring is unpredictable.

Table 6.1 Typical auger sizes available for monitoring well drilling (Central Mine Equipment, 2006).

STANDARD SIZE HOLLOW-STEM AUGER (Central Mine Equipment Company, 2006)		
Hollow-Stem Inside Diameter (inches)	**Flighting Diameter (inches)***	**Auger Head Cutting Diameter (inches)**
2 1/4	5 5/8	6 1/4
2 3/4	6 1/8	6 3/4
3 1/4	6 5/8	7 1/4
3 3/4	7 1/8	7 3/4
4 1/4	7 5/8	8 1/4
6 1/4	9 5/8	10 1/2
8 1/4	12 1/4	13

*NOTE: Auger flighting diameters should be considered minimum manufacturing dimensions.

The use of hollow-stem augers may be hindered by "heaving sands," which occur when a confined, saturated sand unit is encountered. Infiltration of the sand and water into the augers causes them to bind. Common strategies to alleviate this include (Aller et al., 1991):

- Water may be added to maintain a positive downward pressure to offset the pressure of the formation.

- Drilling muds can be added to further offset the pressure.

- The lower portion of the auger may be perforated to allow formation water to enter. This will equalize the hydraulic pressure and prevent entrance of sediments. Screened augers (Taylor and Serafini, 1988) have been developed for this purpose, although strength and structural integrity is lost.

- The pilot bit can be kept in place or a knock-out plug or winged clam can be added to the base of the hollow-stem to prevent infiltration.

The most common approach is to add water to the hollow-stem (Aller et al., 1991). If this is done, only clean, potable water of known chemical quality should be used. Drilling muds are not recommended because the quality of water samples and the integrity of the formation matrix may be affected. Screened augers may be viable. The pilot bit, knock-out plug or winged clam may not be useful when formation samples are needed because the removal of these devices to sample will result in the entrance of sand. The knock-out plug may be useful if prior site characterization eliminates the need for the collection of formation samples.

CABLE TOOL

The cable tool is the oldest drilling method and is readily available throughout Ohio. A heavy string is dropped repeatedly to penetrate the subsurface. The bit crushes rock and causes loosening and mixing in unconsolidated formations (Driscoll, 1986). When penetrating unconsolidated materials, outer casing must follow the bit closely as the boring is advanced to prevent caving. The outer casing often is driven ahead of the hole bottom to prevent cross-contamination (ASTM Method D6286-98). The cuttings are removed periodically with a bailer.

Cable tools drill a wide variety of hole diameters to almost unlimited depths. Individual water-bearing zones and changes in formation often are more easily identified with cable tool drilling than with other methods (e.g., smearing along sidewalls generally is less severe and thinner than with hollow-stem augering). Representative samples can be collected by driving tools (e.g., split-spoon) ahead of the hole bottom. Well installation and development are relatively easy when this drilling method is used. Additionally, the method typically produces a low volume of fluids and cuttings that need disposal (Davis et al., 1991).

Cable tool does have some disadvantages. The rate of penetration is very slow, with rates of 10 to 20 feet per day common (Davis et al., 1991). Problems with "heaving" sands are possible, just as with the hollow-stem auger. When drilling through unsaturated materials, water must be added to form a slurry so cuttings can be bailed. Finally, the driven outer steel casing is not adequate for monitoring well design. The undesirable effects of the presence of the steel casing can be avoided by installing an inner casing of the proper composition. The driven casing is retracted by driving it upward or raising it with hydraulic jacks; however, it may be difficult to remove long strings without special equipment.

For most site conditions and investigative goals, cable tool is an acceptable alternative to hollow-stem augering. Its ability to penetrate both rock and unconsolidated formations with the limited introduction of fluids make it an excellent option. In general, cable tool drilling is recommended for installation of large diameter wells (6-10 inch well casing) to all depths in unconsolidated and unsaturated conditions. It also is an adequate substitute to hollow-stem augering where hollow-stem augering is not feasible (i.e., deep wells in unconsolidated formations, or drilling through cobbles and boulders). However, the rate of drilling can be slow, which may limit the feasibility of cable tool.

DIRECT ROTARY

Direct rotary drilling is known for the speed at which it penetrates. A bit is rotated against the sides of the borehole. Circulation of fluids (i.e., water, mud, or air) (Figure 6.2) lubricates and cools the bit, removes cuttings, and maintains and seals the borehole wall. The fluid and cuttings return to the surface between the drill pipe and borehole wall.

One of two methods are used to rotate the drill bit: a table drive or a top head drive. The rotating motion of the table or top head is transferred to the drill rods, which rotate the bit (SCCGW, 2000).

Several types of bits may be utilized, including drag, roller cone, and tricone. Drag bits are used to penetrate unconsolidated and semi-consolidated deposits. Roller cone bits are preferred when drilling through consolidated rock. Tricone bits are effective for every type of formation (Driscoll, 1986).

In-situ samples may be taken by using a bit with an opening through which sampling tools can fit. However, circulation must be broken to collect samples. Though samples can be obtained directly from the stream of circulated fluid by placing a collection device in the discharge flow, their quantity is insufficient.

Water Rotary

Water rotary is effective for penetrating most hydrogeologic environments (U.S. EPA, 1992). It can readily penetrate both soil and rock to essentially unlimited depths (ASTM Method D6286-98). However, it is recommended only where the water will have limited effects on the formation matrix and ground water chemistry. Clean, potable water of known chemical quality transported from off-site should be used. This method works best when penetrating rock formations where a stable borehole can be maintained.

Use of water rotary is limited because the water may mix and/or react with formation water and hamper the identification of water bearing zones. In addition, the water cannot maintain the borehole wall or prevent the in-flow of fluids from unconsolidated formations, nor can it prevent cross-contamination. It may be desirable to drive casing during drilling. Another option is to complete a multiple-cased well where each section is grouted and successively smaller diameter holes and casing are completed. Heaving sands may cause a problem unless proper pressure can be maintained in the borehole water column.

Air Rotary

Air rotary involves forcing air down the drill string to cool the bit and remove cuttings through the annulus (Aller et al., 1991). No muds are used that "cake" onto the borehole wall, although water and/or foams often are added to improve penetration rates (foam should not be used because it can affect the borehole chemistry (ASTM Method D6286-98). Air removes cuttings effectively and maintains a clean borehole wall, thus allowing for a greater ease in well completion and development. This method can provide a wide range of borehole diameters and is readily available throughout Ohio.

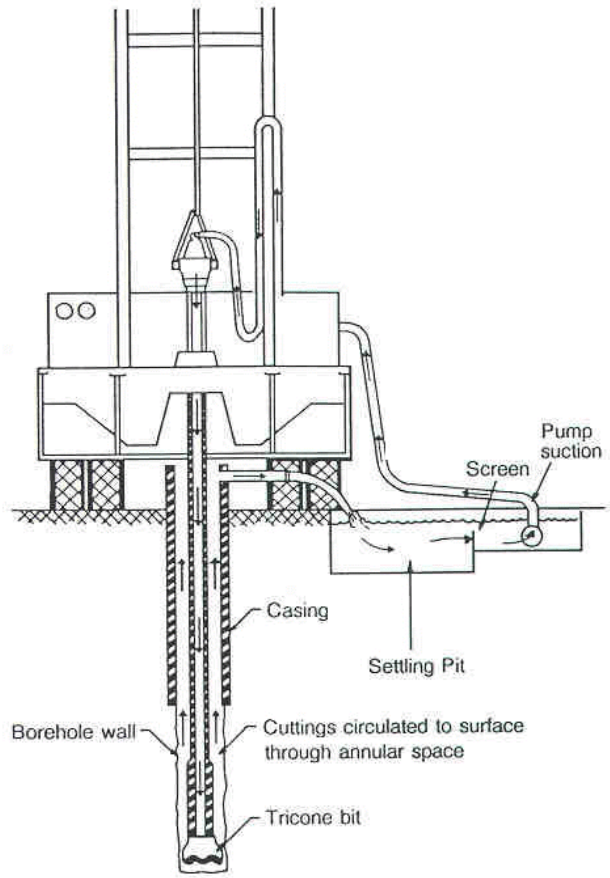


Figure 6.2 Diagram of a direct rotary circulation system(Source: Aller et al, 1991; after National Water Well Association of Australia, 1984).

Air rotary is best justified for penetrating rock (competent or fractured). The depth of drilling is unlimited for all practical purposes (ASTM Method D6286-98). Its use in unconsolidated formations is limited due to potential borehole instability. Overburden casing is commonly necessary (ASTM Method D6286-98). Hollow-stem augers are often used to drill through the unconsolidated deposits, while air rotary is used to complete boreholes into the bedrock.

The identification of thick water-bearing zones is relatively easy, but the identification of thin zones within dry formations can be difficult due to the pressure of the air, its drying effects, and sorption of moisture by the cuttings. Where thin zones are anticipated, drilling should be slowed or stopped to allow any ground water to enter the borehole. This method will work only for the uppermost zones because shallow infiltration hinders the detection of lower zones. Increased grain size of cuttings also may aid in the identification of water-bearing zones as the size of cuttings, typically fine-grained, increases once water is encountered or added.

A disadvantage of air rotary is that compressors often introduce hydrocarbon-related contaminants to the borehole. As a result, in-line filters should be installed and checked regularly for clogging. Conversely, the air stream can potentially strip volatile contaminants from the borehole wall. In addition, control and containment of cuttings at contaminated sites may be difficult. Added safety precautions should be considered due to the abundance of dust, mists and potential volatilization of organic compounds.

Down-hole hammer bits often are substituted for the roller cone bit for a percussion effect to speed penetration through very hard rock (Aller et al., 1991), boulders, and cobbles. A pneumatic drill hammers the rock while the bit is slowly rotated (ASTM Method D6286-98). However, because oil is required in the air stream to lubricate the hammer bit, this technique is not recommended.

The potential for cross-contamination is great due to the lack of casing to seal off specific zones. Therefore, air rotary techniques should not be used when upper layers are contaminated. Another concern is the effect on formation geochemistry and water quality due to the introduction of air. Air can change redox state and also may enhance biodegradation and volatilization. Through time and proper well development, these effects eventually may disappear. It is important that knowledge of the local geochemistry and potential contaminants be obtained and weighed into the determination of whether the method is appropriate.

Air Rotary with Casing Driver

A casing driver can be used with air rotary as the bit advances. This allows unconsolidated formations to be penetrated because the driven casing prevents borehole collapse (Aller et al., 1991). Moreover, the casing seals off contaminated water-bearing zones and can prevent cross-contamination (ASTM Method D6286-98). Normally, the bit is advanced 6 to 12 inches ahead of the casing. It also is possible to advance the casing ahead of the bit and use the drill to clean out the casing. This technique may be necessary for caving and slumping formations and can minimize air contact with the formation.

Air rotary with a casing driver is most applicable for penetrating unconsolidated formations where gravel and boulders exist and air introduction is acceptable. It also may be useful for drilling through unconsolidated formations to depths that the hollow-stem auger cannot attain, although increased friction may hinder penetration below 200 feet in dry, unconsolidated materials (Davis et al, 1991). Telescoped boreholes and casing may help overcome this problem.

Air rotary with a casing driver can be used when both rock and unconsolidated formations must be penetrated. The driver is used to complete a cased borehole through the unconsolidated materials and strict air rotary methods are used once rock is encountered. When completing a monitoring well, the surface casing can be driven upward to expose the well intake once the screen and casing have been installed. The filter pack and annular seal are installed as the driven casing is retracted. Woessner (1987) provided additional information on the air rotary with casing driver method.

Air rotary with casing driver has several disadvantages. The equipment is expensive and not readily available. Extracting the casing can damage the well screen (ASTM Method D6286-98).

Mud Rotary

Mud rotary is common in the oil and water well industry. Typically, bentonite-based mud is added to maintain positive pressure and the borehole walls. The introduction of mud generally "cakes" the formation with fine material that must be extracted during well development. This virtually prevents the identification of water-bearing zones. Also, mud commonly infiltrates and affects water quality by sorbing metals and polar organic compounds (Aller et al., 1991). If organic polymer additives are used, bacteria levels in the formation will increase and cause local biodegradation that may affect organic compound analysis (Aller et al., 1991). Only in rare cases should this method be used. Prior consultation with Ohio EPA is recommended before drilling with mud.

Dual-Wall Reverse Circulation

Dual-wall reverse circulation rotary involves the circulation of either mud, water, or air between inner and outer casings of the drill string (Aller et al., 1991) (Figure 6.3). The inner casing rotates, acting as the drill pipe, while the outer pipe acts as casing. The fluid is pumped down the outer casing to cool and lubricate the bit. The fluid then returns to the surface with cuttings through the inner casing. The dual wall maximizes the energy at the bit with minimal loss of fluids. The outer casing allows for stabilization of the borehole, prevents caving around the bit, minimizes cross-contamination from cuttings, and allows minimal vertical contaminant migration.

This method may not be readily available in most areas of Ohio. It is best suited for deep (>150 ft.) drilling through unconsolidated materials, but it is also efficient for penetrating rock. Dual-wall reverse circulation can drill rapidly to depths exceeding 1000 feet. Wells may be completed in the open hole or through the inner casing. Wells completed in the inner casing are limited to a maximum casing diameter of four inches (Strauss et al., 1989); however, with this size, it is often difficult to install the filter pack and annular seal through the drill string. A variety of fluids are utilized with the dual-wall method. The introduction of mud is not recommended. Only clean, potable water (pre-analyzed with rigid QA/QC) should be used. If air is used, in-line filters are necessary to prevent the introduction of lubricants into the hole. Down-hole air hammer bits often are used with the dual-wall method. As with air rotary, the need for lubricants in the hammer bit makes this tool unacceptable.

Strauss et al. (1989) discussed applications of the dual-wall method and a percussion driver system. The driver advances the outer wall pipe by force instead of rotation. As open-faced bit is used that breaks the formation into fragments small enough to pass through the inner casing. These larger samples allow for more accurate determination of formation characteristics than do the pulverized cuttings of the rotary method. Split spoon samplers and Shelby tubes may be inserted through the inner casing and the open-faced bit to sample undisturbed material ahead of the drill string. Penetration rates of 60 ft/hr in unconsolidated sediments to depths of 300 to 450 feet are possible. A third outer casing can be driven while the dual-wall string advances. This is called "triple-wall" drilling. The extra casing is used to prevent cross-contamination by sealing off an upper, shallow, contaminated zone when drilling to a lower zone.

RESONANT SONIC

Sonic drilling, rotasonic, sonicore, vibratory, rotosonic, or resonant sonic drilling all refer to the same technology. The resonant sonic drilling method is a relatively new technique that is being used successfully in Ohio. The method performs most efficiently at depths of 30 to 300 feet. It combines rotation with high frequency vibration to advance a core barrel to a desired depth. The vibration is stopped, the core barrel is retrieved, and the sample is vibrated or hydraulically extracted into plastic sleeves or sample trays (Dustman et al., 1992). This drilling technique vibrates the entire drill string at a frequency between 50 and 150 cycles per second. When the vibrations coincide with the natural frequency of the steel drill rod or casing a natural phenomenon called resonance occurs. Resonance allows the drill rig to transfer the vibrational energy into the top of the drill string, allowing for very fast (up to 1 foot/second in certain formations) penetration rates (Boart Longyear Co.). Monitoring wells can be installed through an outer casing.

Continuous, relatively undisturbed samples can be obtained through virtually any formation. Conventional sampling tools can be employed as attachments (i.e., hydropunch, split spoon, shelby tube, etc.). No mud, air, water, or other circulating medium is required. The sonic method can drill easily at any angle through formations such as rock, sand, clay permafrost, or glacial till.

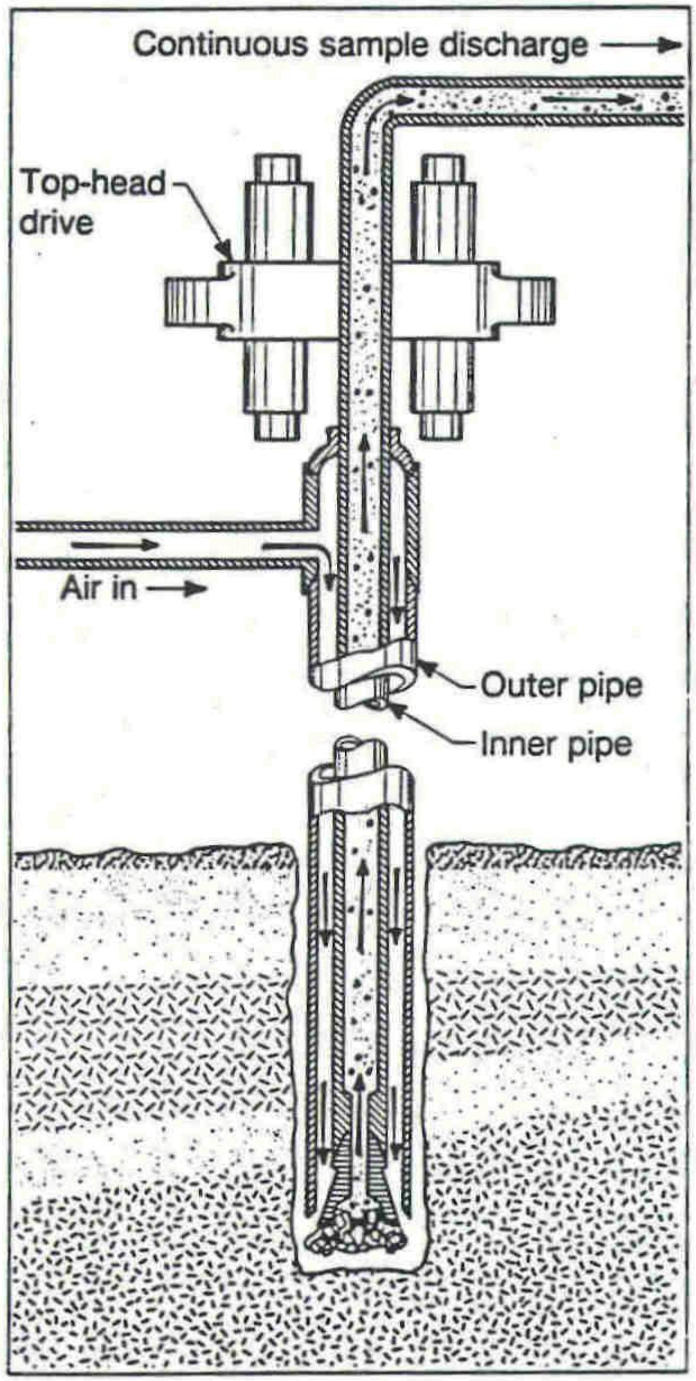


Figure 6.3 Diagram of the dual-wall reverse circulation method (Source: U.S. Bureau of Reclamation Earth Manual, Part I, 3rd ed.)

Case histories of projects using the method demonstrate excellent results but indicate several problems (Barrow, 1994). One of the major disadvantages is the limited availability of the rigs and experts to operate them. Current rigs are operated somewhat by feel and by ear. Although numerous gauges monitoring hydraulic pressures are usually present, successful drilling is accomplished because of the skill of the driller. In addition, the equipment is relatively expensive and the cost per foot of penetration is higher than for conventional methods; however, the method has been shown overall to be more cost- and schedule-effective for hazardous waste site characterization (Barrow, 1994). Penetration rates of 15 to 60 feet per hour were cited by Barrow (1994). In addition, the method minimizes the amount of waste by-products generated.

The resonant sonic method can create elevated temperatures in samples from certain formations. This is a potential problem when projects are evaluating the occurrence of volatile organic compounds (VOCs) (ASTM Method D6286-98).

Another potential problem is that the speed of sample generation may overwhelm the geologist responsible for logging the borehole. In addition, the amount of samples to be tested may be beyond the capacity of a laboratory to analyze on a timely schedule if it is not prepared to handle large quantities. If the project manager recognizes this, he/she can plan for these problems prior to the start of drilling. An additional problem is that the method may destroy soft bedrock (i.e., shales); therefore, sample recovery may be low.

OTHER METHODS

Several other methods are common in the geotechnical industry, including solid flight augers, jet percussion, reverse circulation, hand augers, and manual driving. While generally not recommended for monitoring well installation, there may be exceptions where these methods may be justified. In these cases (as in all others), the responsible party should document the rationale used for the choice.

Solid flight augers function just as hollow-stem augers except that the stem is solid. This prevents the collection of in-situ formation samples. Well installation can be conducted only in stable formations because maintaining an open borehole below the water table after auger removal is often difficult. The hollow-stem auger provides the same function and is more versatile. Therefore, hollow-stem augers are preferred at all times.

Reverse circulation is, in principle, the same as the rotary method but with fluids flowing in the opposite direction. The fluid flows down the borehole annulus to the bit and is returned with the cuttings up the drill string. Reverse circulation differs from the dual-wall method due to the lack of an outer casing wall to manage the fluid and prevent its contact with the borehole wall. This method typically is used to drill large diameter boreholes.

Jet percussion is used infrequently and involves injecting water under pressure down the drill pipe against a wedge-shaped bit. The drill string is lifted and dropped repeatedly during drilling to loosen the soil (ASTM Method D6286-98). Its use is limited to shallow (<150 ft.), unconsolidated deposits with a maximum casing diameter of 4 inches. A hollow-stem auger is the preferred method for these conditions. The injection of fluid, potential for cross-contamination, and limited well diameter restrict the desirability of this method. Jet wash drilling is similar to jet percussion with the exception that the drill bit is not dropped during drilling (ASTM Method D6286-98).

Hand augers are most applicable for shallow piezometer and lysimeter installation. They can reach a depth of 15 feet in unconsolidated materials. This method only can be used to penetrate cohesive materials because a stable borehole wall is necessary for well installation. Generally, the borehole cannot be advanced below the water table.

Driven well installation involves the insertion of a well point (or screen) and casing into the subsurface by hand driving or with a large weight (Figure 6.4). Well points consist of a well screen with a hardened point on the end of the screen, and are installed only in unconsolidated formations (SCCGW, 2000). Driving the device through fine silts, clays, and boulders is often very difficult. Depths of 50 feet or less are common.

Driven wells should not be used as permanent data collection points. As the tool is driven, it tends to smear clays, preventing ground water from entering the screen and, subsequently, hindering well development. The annular space remains unsealed; therefore, the potential for vertical movement of surface water and/or contaminants increases. Furthermore, formation samples cannot be collected, which hinders proper screening and prevents geologic and contaminant characterization.

This method has greater application for plume delineation and tracking studies, where reconnaissance investigation can help determine the extent of contamination. In these situations, prior knowledge of subsurface geology, water-bearing zones, and sampling depths is necessary. Properly constructed monitoring wells should be installed to verify the data.

Larger volumes of water/mud are needed for this method than for the direct rotary method. The potential for large losses of fluids often is present when drilling through permeable formations. This can cause extensive ground water quality degradation around the borehole.

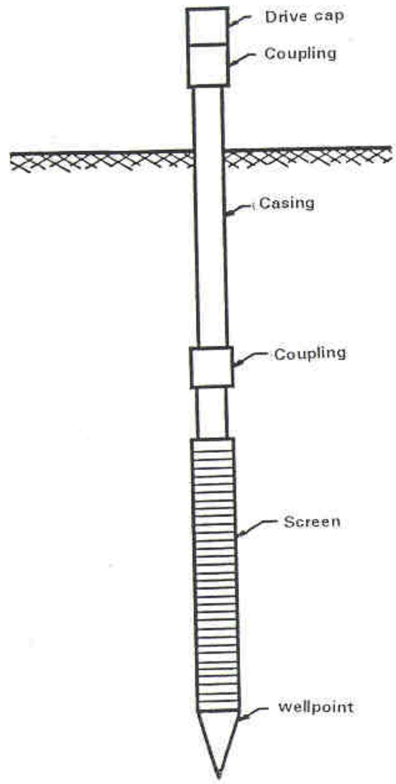


Figure 6.4 Diagram of a well point (Source: Aller et al., 1991).

GENERAL RECOMMENDATIONS

General recommendations can be provided regarding selection of drilling methods and practices for sites in Ohio and the factors that dictate the choice. Experience indicates that geology is the primary factor for most sites. Table 6.2 summarizes the methods that generally apply for various geologic environments. Hollow-stem augering is recommended whenever possible. Resonant sonic is also favored; however, because of its limited availability and application, recommended conventional methods are generally accepted in its place.

Shallow wells in the glaciated portions of northern, western and central Ohio usually can be installed with hollow-stem augers, although penetration of deep, sandy materials may not be possible. Drilling through the consolidated materials at the surface of eastern Ohio may require use of cable tool or air rotary techniques. Air rotary with casing driver may be appropriate to retain the upper unconsolidated and weathered materials as the underlying bedrock is penetrated. Hollow-stem augering may be applicable in eastern Ohio to drill through alluvial deposits and unconsolidated and weathered surface deposits overlying bedrock. Cable tool or air rotary methods may be necessary in western Ohio to penetrate the bedrock underlying the unconsolidated shallow glacial deposits.

Methods requiring use of fluids (air, water, and mud) should be avoided whenever possible. If fluids are necessary, water and air are more acceptable than mud, which can have a long-term effect on ground water quality. Water used should be recovered. All fluids and cuttings should be routed directly to the surface and isolated from contact with the formation. Air rotary with casing driver and the use of air with the dual-wall reverse circulation method provide protection from air infiltration. The use of water for cable tool drilling may be acceptable because it is only necessary while drilling through the unsaturated zone.

Table 6.2 Summary of drilling methods recommended for different types of geologic materials.

GEOLOGIC MATERIALS	DRILLING METHODS				
	Hollow-Stem Augers	Cable Tool	Dual-Wall Circulation	Air-Rotary With Casing Driver	Resonant Sonic Method
Unconsolidated	X	X	X	X	X
Consolidated, Fractured and/or Weathered		X	X	X	
Consolidated, Competent		X		X	X

SAMPLING SUBSURFACE SOLIDS

During drilling of a monitoring well borehole, samples of formation material should be collected to help in the selection of filter pack and well screen sizes and aid in the placement of the well intake. Field and laboratory analysis of the samples also can provide information that can be used to prepare geologic cross-sections, identify water-producing zones, and determine contaminant concentrations.

Appropriate tools should be used. Cuttings brought to the surface are not suitable as samples because they are pulverized and do not reflect the true nature of the formation. Furthermore, accurate determination of the horizon of the cuttings is often difficult or impossible.

SUBSURFACE SAMPLERS

Most samplers have been designed to sample ahead of a bit. Types include thin-wall, split-spoon, core barrel, and continuous tube. The tool chosen should provide samples that represent the subsurface environment to the highest degree possible. Selection should be based on site geology, the drilling method, and investigative goals. All of the samplers discussed here are acceptable.

Solid-Barrel Samplers

Solid-barrel samplers are generally steel or stainless steel cylinder generally between 12 and 60 inches in length and between 1 and 6 inches in diameter. They may be used with liners that may be made of brass, stainless steel, or plastic. Solid-barrel samplers are often used with DPT systems and are discussed in Chapter 15 - Use of Direct Push Technologies for Soil and Ground Water Sampling.

Split-Barrel Sampler

The split-barrel (also called split-spoon) sampler is commonly used for collecting unconsolidated formation samples (Figure 6.5). This tool works efficiently with hollow-stem augers, which allow for sampling directly through the auger and ahead of the bit. It also works efficiently with cable tool but offers limited use with rotary. The sampler is comprised of an 18 to 24 inch long cylinder that splits in half length-wise to yield the cored sample. They are generally available in diameters from 1 to 3.5 inches (Ruda and Farrar, 2006). Samples are collected by lowering the tool to the base of the borehole with drill rods and driving it into the subsurface with a 140 pound weight (or "hammer"). The sampler should be driven about 6 inches less than its length to avoid sample compression. Coarse material sometimes catches in the sampler, preventing complete recovery. To help reduce sample loss, retainers have been designed (Figure 6.6). A complete description of collection of split-spoon samples is contained in ASTM D1586-99 (1994).

Split-spoon samples are acceptable for formation identification and characterization. However, they are considered to be "disturbed", due to the relatively large wall thickness of the split-spoon, which causes compaction of the sediment as it enters. Because of this compaction, this tool should not be used when samples are to be submitted for laboratory analysis for physical parameters (such as hydraulic conductivity). Split-spoon samples are acceptable for chemical analysis, however. They are often used in conjunction with liners for ease of sample collection and removal (Ruda and Farrar, 2006).

Standard Penetration Tests (ASTM, Method D1586-99) typically are conducted with the split-spoon sampler for a relative indication of formation consolidation. Generally, this involves lifting and dropping a weight across a 30-inch span and recording blow counts ("N") for each 6 inches of advancement. "Sample refusal" occurs when blows exceed 50 with little or no downward progress. The sampling effort can be stopped at this point and drilling may continue (if possible).

Thin-wall Sampler

The thin-wall sampler is of two types: open (or Shelby Tube) or piston-type. Both are used for collecting undisturbed, in-situ soil samples (Figure 6.7). According to ASTM Method D669-98, an undisturbed sample is collected taking every precaution to minimize sample disturbance. The wide diameter and thin walls of the tube allow for very minimal disturbance. The tube is attached to the drill rods and slowly pushed

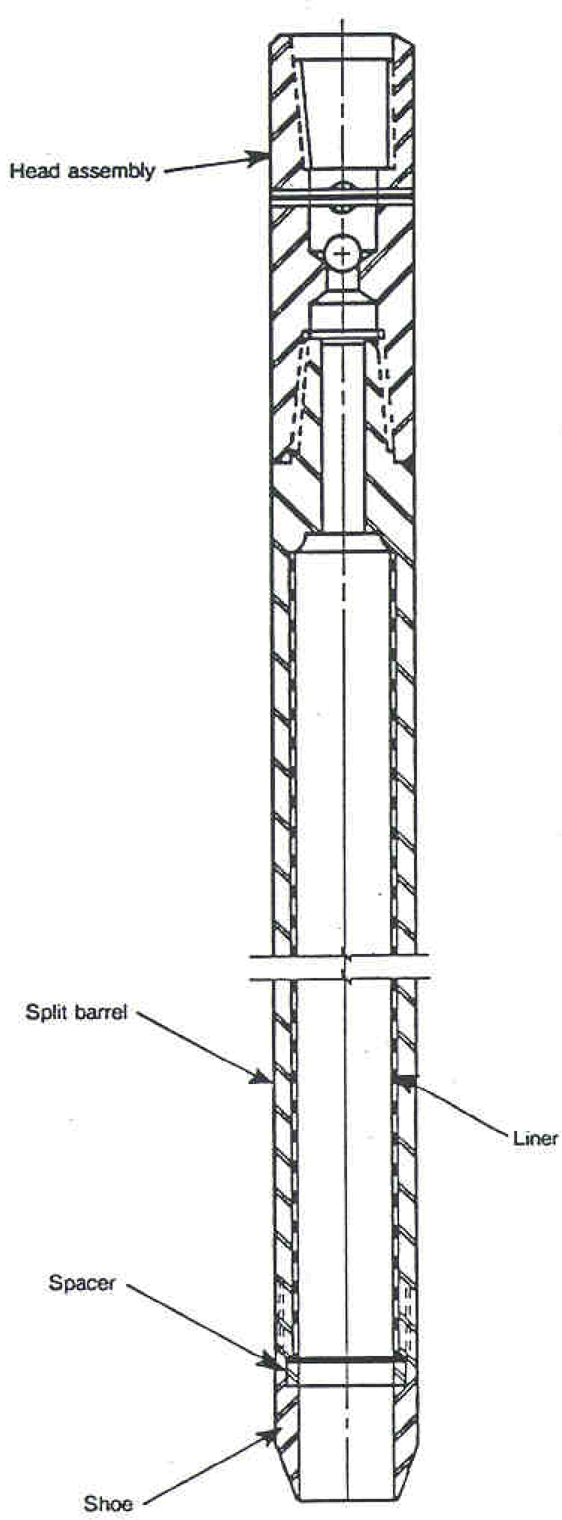


Figure 6.5 Diagram of a split spoon sampler (Source: Aller et al., 1991; after Mobile Drilling Company, 1982).

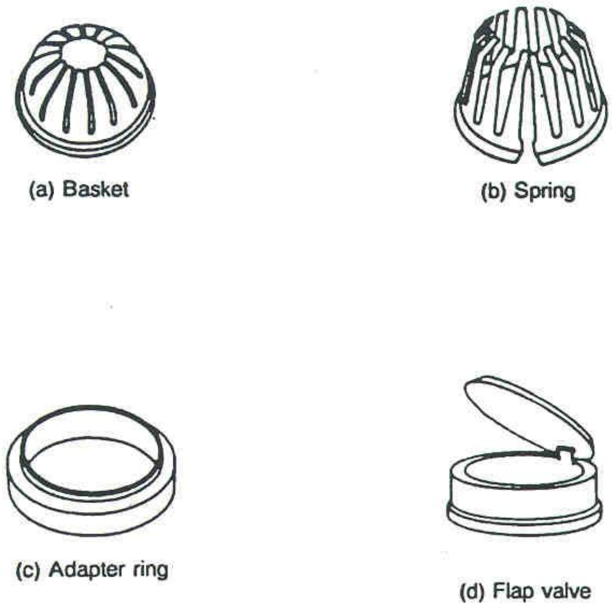


Figure 6.6. Types of sample retainers (Source: Aller et al., 1991; from Mobile Drilling Company, 1982).

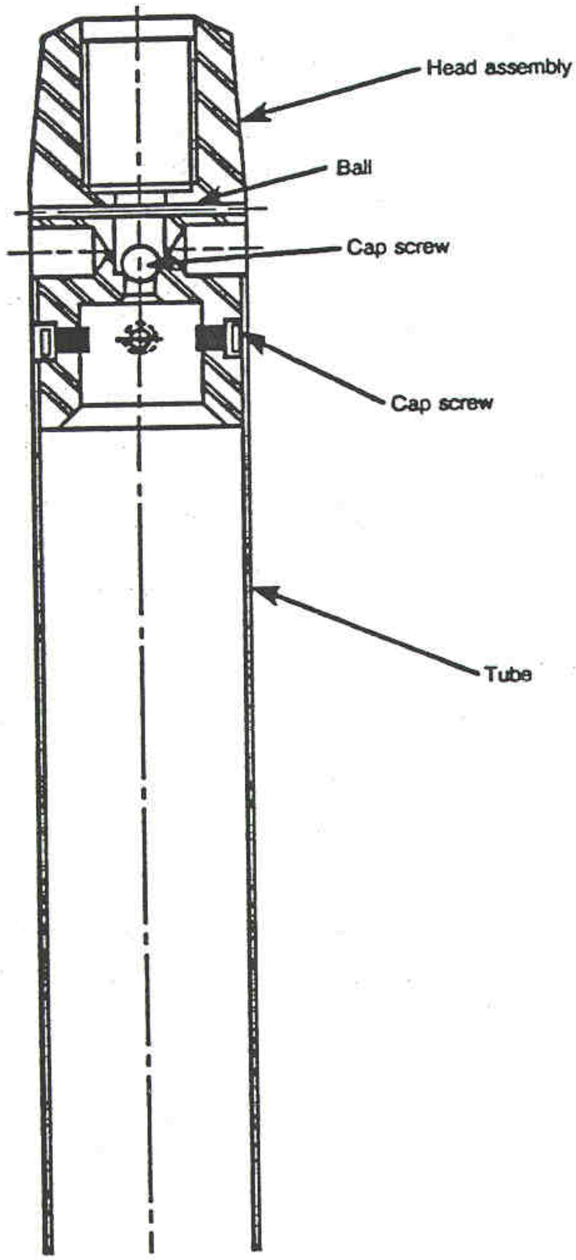


Figure 6.7 Diagram of a thin-wall sampler (Source: Aller et al., 1991, from Acker Drilling Company, 1985).

ahead of the existing hole. Upon removal, the tube should be sealed on both ends and transported as an entire unit for analysis (e.g., permeability, moisture content, porosity etc.). The "top" or "up" direction should be marked so that the laboratory will orient the sample correctly. The procedures are described in detail in ASTM Method D1587-00.

The thin-wall sampler is primarily used in soft cohesive sediments and may not be effective in sand or non-cohesive sediments (ASTM Method D6169-98). When sampling dense, cohesive materials or coarse gravel, its limited structural strength may prevent penetration. A standard 2-inch inside diameter device often will collapse in soils with "N" values of 30 or greater. Thin-wall samplers can be used for collection of samples for laboratory testing of in-situ physical and hydraulic properties, chemical analysis and detailed visual description (ASTM Method D6169-98).

Vicksburg and Dennison Samplers

The Vicksburg and Dennison samplers are specialized tools that are used less commonly (Figure 6.8). Both are basically reinforced thin-wall samplers with larger diameters that cause less sample deformation. The ***Vicksburg sampler*** has a 5.05-inch inner diameter and is structurally much stronger than the thin-wall sampler.

The ***Dennison sampler*** is a double-wall device with a thin-wall inner tube. It functions as either a soil or rock core sampler (ASTM Method D6169-98). The outer tube is designed to penetrate dense, cohesive formations and highly cemented unconsolidated deposits. It may be used to collect undisturbed samples in dense materials (ASTM Method D6169-98). The Dennison sampler is available in standard sizes of 3 1/2, 4, 5 1/2, and 7 3/4-inch outer diameter. Measures should be taken to ensure that the auger, borehole, or drill stem can accommodate the device.

Piston Samplers

Piston samplers include an internal sleeve, a piston and either hydraulics or mechanical mechanisms for regulating movement between the inner sleeve and the piston (Figures 6.9 and 6.10). Piston samplers are primarily used for geotechnical sampling, but used in conjunction with a clam-shell tool at the auger head (Figure 6.11) they can be used for retrieving samples in heaving sand situations. Fixed piston samplers can be used in saturated or non-cohesive sediments where recovery is poor (ASTM D6169-98). Piston samplers are often used with DPT rigs and are discussed Chapter 15 - Use of Direct Push Technologies for Soil and Ground Water Sampling. Further discussion on the use and application of piston samplers can be obtained from papers by Zapico et al. (1987) and Leach et al. (1988).

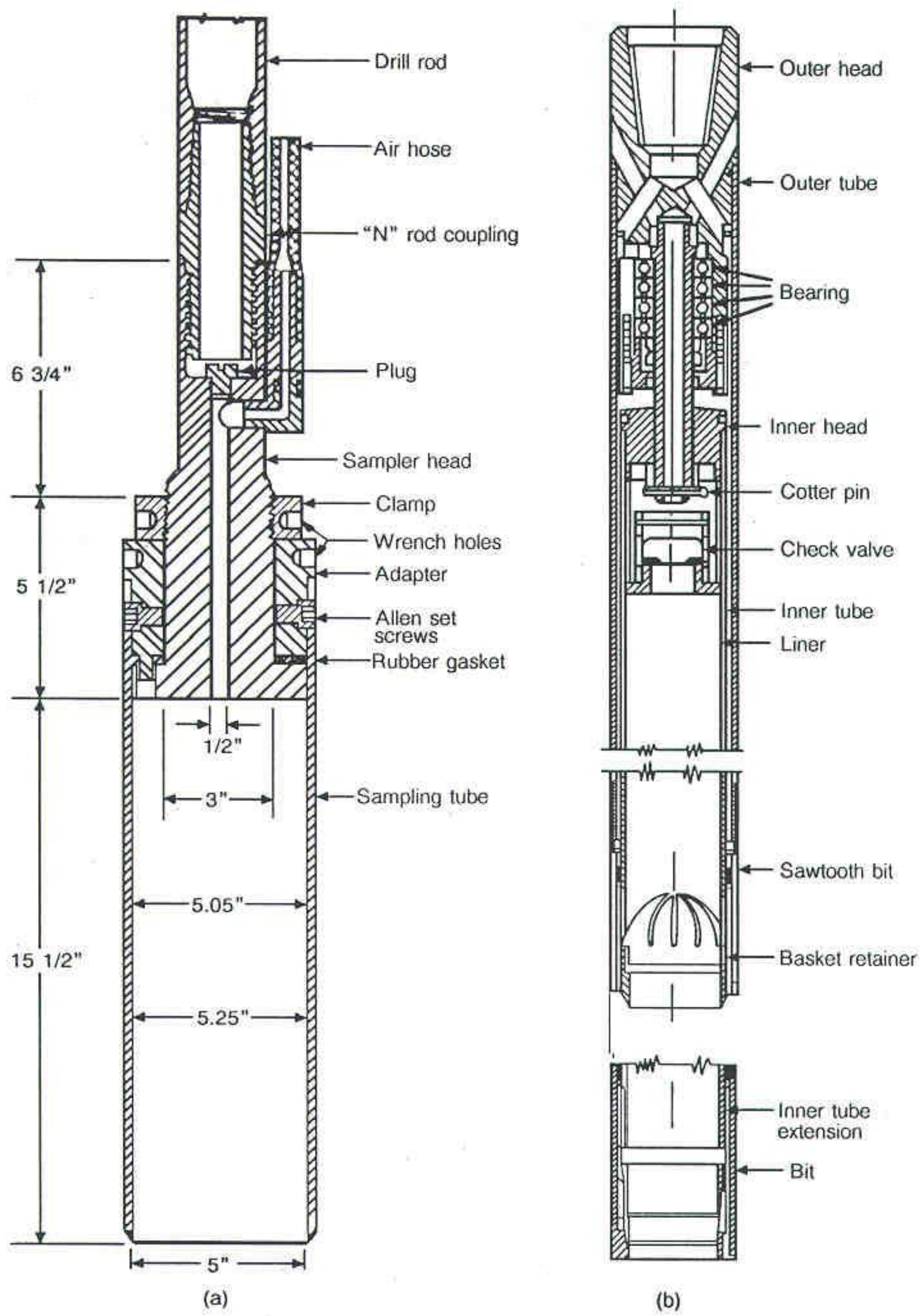


Figure 6.8 (A) Vicksburg sampler - Source: from Krynine and Judd (1957). (B) Dennison sampler - Source: from Acker Drilling Company (1985) (Aller et al., 1991).

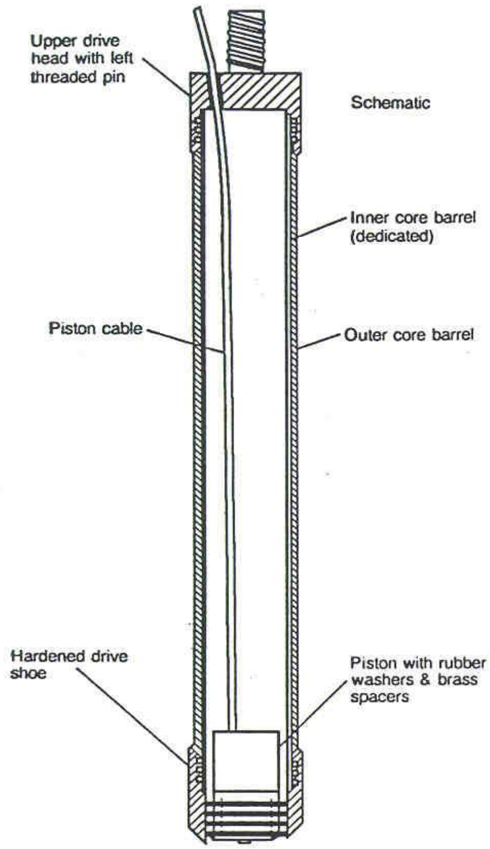


Figure 6.9.Internal sleeve wireline piston sample (Source: Aller et al., 1991; from Zapico et al., 1987).

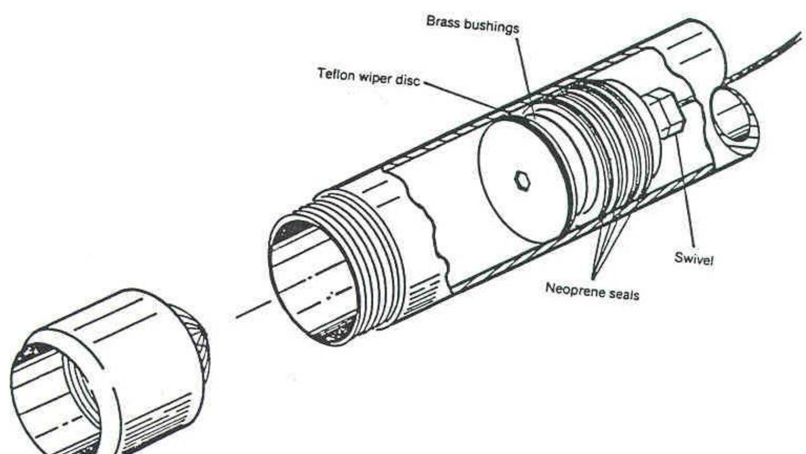
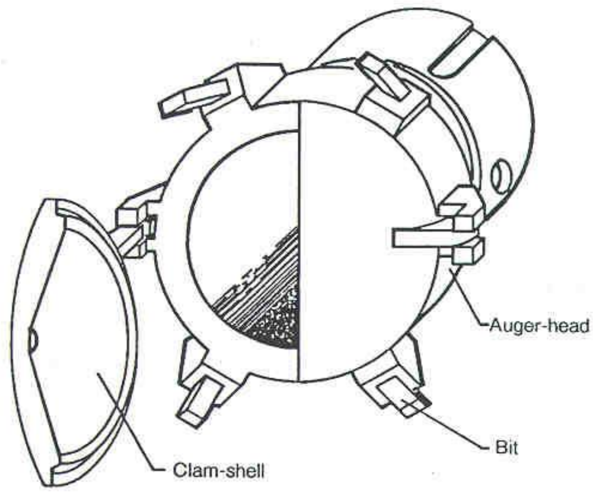


Figure 6.10: Modified wire piston sampler (Source: Aller et al., 1991 from Leach et al., 1988)



6.11 Clam-shell fitted auger (Aller et al., 1991; from Leach et al., 1988).

Continuous Sampling Tube

A tube has been developed to allow continuous sampling of unconsolidated material. The device can be used with hollow-stem augering. A 5-foot-long tube is attached ahead of the auger. A drilling rod with a special bearing head holds the continuous sampler in place. The nose of the sampler is located directly in front of the bit and advances with the auger. Once full, the column can be retrieved through the hollow-stem and a new tube inserted. Continuous sampling tubes are available for 3.25, 4.25, and 6.25 ID hollow stem augers (Ruda and Farrar, 2006).

Each tube is similar to a long split-spoon in that it can be split apart to expose the sample for field identification and description. This tool enables faster and more efficient sampling than the split-spoon and thin-wall devices due to the greater length of the sample collected. This method may be most efficient when depth of sampling is great (> 100 feet) and when penetrating relatively fine-grained, cohesive formations where sample recovery is good. Sample recoveries and the use of this device may be limited in coarse-grained sands and gravels. Heaving sands may be a problem when sampling non-cohesive materials within the saturated zone. If samples are desired for laboratory analysis of physical parameters (permeability, etc.), a thin-wall sampler should be used at the desired intervals. Because the continuous sampling tube is not driven into the formation, blow counts to determine relative competency are not obtained. Instead, a hand penetrometer can be used to gather data from the samples.

Core Barrel

When reliable samples of rock formations are needed, rotary drilling with coring is recommended. The conventional and wireline methods are commonly used (Aller et al., 1991). Conventional core tubes are attached to the end of the drill rod and the entire rod, core tube, and bit are removed. A wireline core barrel assembly consists of an inner barrel that can be retrieved independently of the outer barrel through a special drill rod (Winterkorn and Fang, 1975). With both methods, the ease of sample removal is enhanced with a split barrel.

With the conventional method, a carbide or diamond-tipped bit is attached to the bottom of a core barrel. The sample moves up inside the tube as the bit cuts deeper. Both single and double-tube barrels can be utilized. When using single-wall barrels, the drilling fluid circulates between the core and the barrel. The fluid then flows around the bit, cooling it, and exits up the annulus to the surface. Direct contact of fluid with the collected core can destroy and erode soft and/or poorly cemented material. A double-wall barrel can be used to alleviate this problem. In this case, fluid is circulated between the two walls of the barrel, remaining isolated from the core itself. Good recoveries using the double-wall barrel have been attained in unconsolidated silts and clays. (Aller et al., 1991).

The use of the conventional method requires the removal of the drill rods from the borehole to sample. This can be extremely time consuming. The wireline method allows an inner barrel to be brought to the surface without removal of equipment, which offers several advantages: 1) it saves time, 2) it reduces the chance of caving, and 3) it increases bit life by reducing the number of times that it must core through caved material on re-entry into the hole. In addition, an optional feature on the wireline barrel is a water shut-off valve that causes the pump pressure to rise, thereby alerting the driller to a core block and averting unnecessary grinding (Winterkorn and Fang, 1975).

Core losses can be a problem in coarse-grained materials. Losses may be caused by erosion of the material by the circulating fluid. Appropriate core-catching devices, controlling the speed of rotation and rate of advancement, keeping the volume of drilling fluid to the minimum necessary, and minimizing the vibration of the drill rods can all help minimize core losses. Loss of cores can also occur when coring through more consolidated material if the rock is highly fractured or broken, or if a rock fragment becomes wedged in the core bit or barrel (Ruda and Farrar, 2006).

IMPLEMENTATION

Once a sampling device has been selected, potential field problems, sampling interval, formation sample storage and preservation, data requirements, sample testing, and quality assurance/quality control need to be considered.

Common Field Problems

Potential problems that can affect field decisions and interpretation of the sampled materials must be considered. Loss of non-cohesive, fine-grained particles from samples may prevent an accurate description of the subsurface. Therefore, it is important that the reliability and amount of sample collected be observed and recorded continually. Additionally, large particles (greater than 1/3 the inside diameter of the sampler) frequently cannot be collected and often are pushed aside or may prevent penetration completely (Aller et al., 1991). In some cases, use of retainers or specialized devices may be necessary. Also, large gravel or cobbles can lodge and prevent sample collection.

When sampling alternating saturated clay/silt and sand formations, it is possible for clay or silt to plug the sampler without the collection of any sand. It is also common for the sample to be compacted inside the sampler. For example, the tool may be driven 2 feet but only collect 1.5 feet or less of sample. Careful observation of samples and prior knowledge of the subsurface may be necessary to ensure that an accurate cross-section is generated.

Sampling Interval

Two basic sample collection intervals are used, continuous and discontinuous. Continuous sampling involves collecting a column of samples that completely represents the drilled borehole. This is the most accurate way to characterize the subsurface. The viability and ease of continuous sampling varies among sampling devices and drilling methods. All of the samplers described here can be utilized continuously except the piston sampler.

Discontinuous sampling allows for collection of samples at variable intervals. A common practice is to collect 18 or 24 inch samples at 5 foot intervals in addition to collection at the contact between two different formations. This method may not allow for a complete and accurate description of a geologic column. Discontinuous sampling may be warranted when well clusters are being installed or extensive study has already been completed and site hydrogeology is thoroughly understood. The role of continuous sampling in hydrogeologic investigations is discussed further in Chapter 3 - Characterization of Site Hydrogeology.

Sample Storage and Preservation

Generally, samples collected for bulk mineralogy and grain size can be stored directly in a clean container without concern for moisture or oxygen conditions. On the other hand, samples submitted for ion exchange need sealed containers because air drying is known to increase ion exchange capacity (EPRI, 1985). Microbial populations also are known to change after drying and rewetting (EPRI, 1985). If anaerobic conditions exist in the subsurface, the container should have all oxygen removed. This is important if the sample is to be analyzed for ion exchange capacity, soluble metal concentrations, or Eh (EPRI, 1985).

Samples collected in thin-wall tubes generally are stored and transported within the tubes themselves. Tubes containing sensitive soils should be shipped in the same orientation they were sampled to prevent possible reshaping of the sample (Ruda and Farrar, 2006, ASTM D4220). Upon removal, the tubes should be sealed and cooled to 4^{o} C. They should not be frozen because freezing can change sample pore structure. For samples to be analyzed for VOCs or where an anaerobic environment must be maintained, the tubes should be sealed with tight-fitting Teflon caps. The caps should be taped and covered with a silicone grease or paraffin sealant. The sealant should not interact with the sample (EPRI, 1985). In general, samplers lined with plastics are not recommended if samples are to be transported within the tube. Plasticizers could leach and/or contaminants could be adsorbed by the liner.

Additional guidance on storage, preservation, and transport has been provided for soil samples by the ASTM in Standard Method D4220 and for soil and rock samples by

(Ruda and Farrar, 2006). It is beyond the scope of this document to provide a complete description of procedures for the collection of formation samples submitted for chemical analysis. For more specific information and procedures, the U.S. EPA (1986b) document, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) should be consulted.

Data Requirements

Logs should be prepared for each boring identifying soil types and features or bedrock lithology. A log should indicate and document the data acquired, as well as any problems that were encountered. For a detailed discussion of data needs for boring logs, see Chapter 3.

DECONTAMINATION

Decontamination is the process of removing or reducing undesirable physical or chemical constituents, or both, from a sampling apparatus to maximize the representativeness of sample analyses (ASTM D5088-02). Without effective procedures, any data generated are subject to critical scrutiny (Nielsen, 2006). The purpose of decontamination is to ensure that representative samples are collected for analysis and to prevent cross-contamination between sites, boreholes, or zones.

The focus of this section is decontamination of field equipment. However, personnel also should implement appropriate levels of decontamination upon exiting the work area. This can range from extensive washes and rinses and appropriate clothing removal in a designated decontaminated zone to a very limited program requiring glove disposal and hand cleaning only. The degree depends mainly on the nature of contamination and the scope of the drilling program. Personnel decontamination should be detailed in a safety plan.

Planning a program for decontamination requires consideration of:

- The location of a designated area for decontamination.
- The types of equipment that require decontamination.
- The frequency that specific equipment requires decontamination.
- Decontamination procedures and cleaning agents.
- The method for containerizing and disposing of decontamination fluids.
- Measures to monitor the effectiveness of decontamination.
- The purpose of the investigation and level of QA/QC required.

In addition, the level of effort for a decontamination protocol should be determined by the purpose of the investigation and the level of QA/QC required.

Decontamination Area

A decontamination area should be designated. At least three zones should be defined, including an exclusion zone, a contamination reduction zone, and a support zone. The intent of this system is to limit the production of contaminated waste and reduce the spread of contamination. It is important that the area be located at a sufficient distance away from the borehole to avoid contamination due to accidental spills. The decontamination area should be upwind of activities that may contribute dust or other contaminants to the solutions used. The process should occur on a layer of polyethylene sheeting to prevent surface soils from coming into contact with the equipment.

Typical Equipment Requiring Decontamination/Disposal

Table 6.3 lists typical equipment requiring decontamination. Porous material such as rope, cloth hoses, wooden blocks, and handles cannot be decontaminated completely and should, therefore, be disposed properly. Personal gear such as gloves, boot covers, and clothing that continually come in contact with equipment, cuttings, and ground water should be cleaned properly or disposed when necessary.

Frequency

Drilling equipment should be decontaminated before and after arrival and between sampling locations. Further activity is necessary when penetrating an upper contaminated zone followed by a lower uncontaminated zone. All sampling equipment should be cleaned between samples. Disposal of gloves, boot covers, tyvek suits, etc. may be necessary during each boring and/or between borings. Higher levels of contamination may require a greater frequency of decontamination (Nielsen, 2006).

Table 6.3 Typical equipment requiring decontamination when drilling and sampling subsurface materials.

FIELD ACTIVITY	EQUIPMENT TO BE DECONTAMINATED
Materials sampling	Sampling devices Sample inspection tools Downhole equipment
Drilling	Drill rig, rod, and bits Augers

Procedures and Cleaning Solutions

The decontamination process and fluids depend on the purpose of the investigation and the level of QA/QC required. For example, procedures used when installing a detection monitoring well network at a newly proposed facility may, in general, require less stringent practices than when investigating known or suspected contamination.

Decontamination activities should be selected based on their chemical suitability, compatibility with the constituents to be removed during decontamination, and the concentrations of the constituents anticipated. For example, when metals are the contaminant of concern, the process should include an acid rinse. If organics are a contaminant, a solvent rinse should be incorporated. The procedure may be complex when more than one contaminant group is under investigation (Nielsen, 2006). Rinsing agents should not be an analyte of interest. As discussed in Chapter 10 – Ground Water Sampling, a sampling event where high levels of contaminants are known or suspected would require the most stringent decontamination procedure, which may involve the use of solvent rinses. In general, solvent rinses should only be used when high levels of organic contaminants are known or suspected to be present. Care should be taken to avoid the any decontamination product (or breakdown products) from being introduced into the sample.

Procedures may be dependent on whether the equipment comes in contact with the collected sample. Sample-contacting equipment includes devices that contact samples that undergo physical or chemical testing (i.e., split-spoon, shelby tube). Non-contacting equipment includes devices that do not contact samples (i.e., augers, drilling rods, drill rig), but do, however, come into contact with contaminated or potentially contaminated materials. Disposable items (i.e., gloves, personal protective equipment, plastic sheeting) would not have to be decontaminated. Table 6.4 outlines recommended decontamination sequences and procedures, derived from the current ASTM Standard D5088-02.

Quality Control Measures

The decontamination procedures should be documented. Additionally, samples should be collected to evaluate the completeness of the process. This generally involves collecting the final rinse or wipe sample and sending it to a laboratory for chemical analysis. The frequency of this evaluation is dependent on project objectives. At a minimum, it is recommended that a QA/QC sample be collected after every tenth wash/rinse. Collection of a rinse or wipe sample before decontamination of the equipment prior to its use can establish a baseline of contaminants that may be present on the equipment (ASTM D5088-02).

INVESTIGATION BY-PRODUCTS, CONTAINMENT AND DISPOSAL

A variety of waste is produced during drilling and sampling that may need to be contained and disposed properly. Typical by-products include: 1) decontamination solutions and rinse water, 2) disposable equipment (gloves, tools, boots, etc.), 3) drilling mud (if used) and borehole cuttings, 4) well development and purging fluids, and 5) soil and rock samples. It is not the intent of this document to define/determine Ohio EPA policy on disposal of these by-products.

All cleansers and rinses should be collected and stored for proper characterization and disposal after use. Collection/storage systems may need to include special concrete or plastic-lined decontamination pads with collection sumps for cleaning large equipment such as rigs. Plastic-lined trenches and/or wash tubs often are used for lighter equipment. Thick plastic sheets typically are placed on the ground around the borehole extending beyond the work area. This prevents contact of the cuttings and drilling fluid with the surface, thereby preventing the spread of contamination.

Table 6.4 Decontamination procedure for soil sampling equipment.

EQUIPMENT CONTACTING SAMPLES
• Wash with non-phosphate detergent and potable water. Recommend using pressure spray filled with soapy water. Use bristle brush made from inert material to help remove visible dirt. • Rinse with potable water. • If analyzing samples for metals, may* need to rinse with 10% hydrochloric or nitric acid (note: dilute HNO_3 may oxidize stainless steel). This rinse is only effective on non-metallic surfaces. • Rinse liberally with deionized/distilled water. • If analyzing for organics, may* need to rinse with solvent-pesticide grade isopropanol, acetone, or methanol, alone or if required, in some combination. This solvent rinse should not be an analyte of interest. This rinse is important when a hydrophobic contaminant is present (such as LNAPL or DNAPL, high levels of PCB's etc.) • Rinse liberally with deionized/distilled water. • Air-dry thoroughly before using. • Wrap with inert material if equipment is not to be used promptly.
EQUIPMENT NOT CONTACTING SAMPLES
• Large equipment should be steam-cleaned or cleaned with a power wash; smaller equipment can be hand-washed with non-phosphate detergent. • Rinse with potable water. • More rigorous procedures than described above may be employed if more stringent QA/QC is desired (e.g., known or suspected subsurface contamination). Source: ASTM D5088-02

*In most cases, solvent rinses will not be needed. Solvent/acid rinses may only be needed when high levels of contaminants are known to be present.

Investigation by-products typically should be collected in 55 gallon drums and stored away from the drilling area. The contents must be characterized to determine if they are solid or hazardous waste, which will dictate the proper disposal method. Solid waste may be disposed at a solid waste landfill. Hazardous waste must be properly transported for either incineration, landfill disposal, and/or treatment. Hazardous waste may not be stored on-site for more than 90 days without a permit. After 90 days, the site may be considered a hazardous waste storage facility and compliance with applicable rules becomes necessary (see OAC 3745-52-34).

CONTROL AND SAMPLING OF ADDED FLUIDS

The addition of fluids should be prevented or controlled whenever possible. If a fluid must be added, the activity should be documented. The amount added should be recorded and full recovery should be attempted during drilling and development. All water used should be potable and of known chemical quality. Sampling of any water or mud added should be conducted. Samples should be analyzed in a laboratory to verify that contaminants were not added to the borehole.

Appropriate air filtering devices should be used and changed regularly if the air rotary technique is used. This is necessary to prevent contamination from the petroleum lubricants used in the compressor.

PERSONNEL SAFETY

The safety of on-site personnel should be a high priority for any site investigation. Contingency plans should be prepared and personnel should be familiar with the procedures. A plan should include responsibilities of personnel, information and procedures for emergencies, decontamination protocols, operating procedures and training for the use of various drilling and safety equipment, site control (site entry and access areas, etc.), and the assessment of environmental exposures and health hazards. Potential hazards include utilities, noise, site conditions (topography, debris, etc.), temperature, chemical, radiation, biological, toxic, and confined spaces. Many of these potential hazards can be identified before site entry through reconnaissance studies. Assistance in locating utilities can be obtained from Ohio's "Call Before You Dig" service (1-800-362-2764). Continual monitoring of the air, soil, and ground water for explosive potential, oxygen content, and VOCs, etc. can help identify hazards or allow for appropriate precautions to be implemented.

The degree of effort for safety depends on the nature and scope of the particular investigation. When drilling in highly contaminated areas, extensive efforts and detailed plans may be necessary. In areas with low- to non-detectable contamination, the level of effort may be less extensive. At all times, the unexpected should be expected. For further information on health and safety issues, see Maslansky and Maslansky (2006), Aller et al. (1991), HWOER (1989), NIOSH (1998), NDA(1986), and 29 CFR 1910.22.

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